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U. S. DEPARTMENT OF AGRICULTURE

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How to GROW RICE IN THE SACRAMENTO VALLEY

THE COMMERCIAL PRODUCTION OF RICE in California began in 1912, when 1,400 acres were grown. By 1920 the area had increased to 162,000 acres.

Rice growing in California is confined mostly to the heavy clay and clay-adobe soils of the lower Sacramento Valley, where abundant water is available for irrigation. Rice requires high temperatures during the growing season, a dependable water supply for irrigation, level land with an impervious subsoil, and good drainage.

Fields on which rice is to be grown should be leveled and the checks laid out carefully, so that water can be applied to them easily and uniformly. Uneven submergence of rice in the checks causes uneven ripening and lowers the market value of the crop.

Land on which rice is to be sown is usually spring-plowed and is then disked and harrowed or the clods crushed with drags. The seed is either drilled or sown broadcast. If the land is to be submerged continuously after seeding to control water grass, it is safer to sow the seed broadcast than to drill. Slacking the clods on drilled fields continuously submerged after seeding may cover the seed too deeply and result in poor stands. Early shallow seeding at the rate of 115 to 130 pounds on new land and 125 to 145 pounds on old land usually gives best results. The leading varieties of rice in California at present are Caloro, Early Wataribune, Colusa, and Onsen.

Weeds, particularly water grasses, are the most troublesome pests in California rice fields. They can be controlled to a considerable extent by deep early submergence.

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HOW TO GROW RICE IN THE SACRAMENTO VALLEY.[1]

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HISTORY.

INVESTIGATIONS begun by the United States Department of Agriculture in the spring of 1909 and continued for three years provided information which indicated the commercial possibilities of rice culture in California. The first commercial rice crop was grown in California in 1912 on Stockton clay-adobe soil in the Sacramento Valley, near Biggs. The high acre yields and large profits from this crop of 1,400 acres received wide publicity, which stimulated interest and resulted in the rapid expansion of the California rice industry. In 1914, 15,000 acres were sown, while in 1915 the crop was grown on 34,000 acres. The high price of rice during the World War naturally caused a further increase in acreage and production. The maximum so far was reached in 1920, when 9,720,000 bushels of rice were produced on 162,000 acres. The acreage in 1921 and 1922 was less than in 1920, the estimate for 1922 being 140,000 acres with a production of 8,260,000 bushels.

Rice is grown in California only in the San Joaquin and Sacramento Valleys. Most of the crop is produced in the Sacramento Valley in Butte, Glenn, Colusa, Sutter, and Yolo Counties.

IMPORTANCE OF THE RICE CROP.

The area on which rice can be profitably grown in the United States is much more limited than that on which most of the other cereal crops can be produced with profit. Rice is, however, well adapted to certain sections.

[1] For a more complete discussion of rice production in California, together with the details of the experiments on which many of the recommendations in this bulletin are based, see Jones, Jenkin W., Rice experiments at the Biggs Rice Field Station in California, U. S. Dept. Agr. Bul. 1155, 1923.

During the 5-year period from 1917 to 1921 the average annual area sown to rice in the United States was 1,083,000 acres and the average annual production 41,107,000 bushels. In the same period the average annual acreage sown to rice in California was 125,244 acres and the average annual production 7,481,000 bushels. During this period California has produced more than one-sixth of the total annual rice crop of the United States on less than one-eighth of the total annual acreage.

The average yield per acre in California is considerably higher than that obtained in other large rice-producing States. The 10-year average yield from 1910 to 1919 for California was 53.9 bushels; for Arkansas, 40.9 bushels; for Texas, 33.8 bushels; for Louisiana, 33.6 bushels; and for the United States, 35.7 bushels per acre.

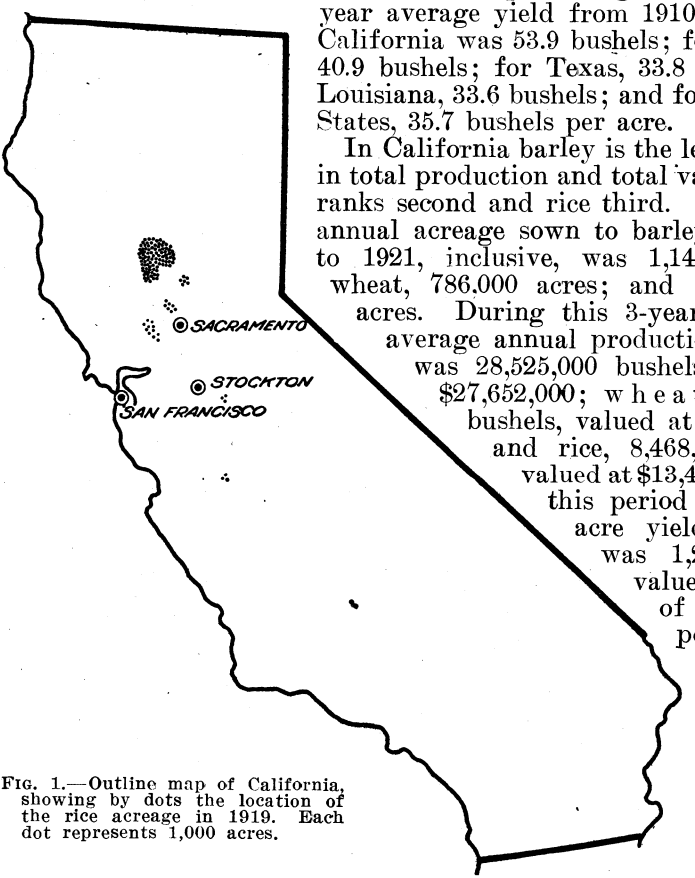

FIG. 1.—Outline map of California, showing by dots the location of the rice acreage in 1919. Each dot represents 1,000 acres.

In California barley is the leading cereal in total production and total value. Wheat ranks second and rice third. The average annual acreage sown to barley from 1919 to 1921, inclusive, was 1,141,000 acres; wheat, 786,000 acres; and rice, 146,000 acres. During this 3-year period the average annual production of barley was 28,525,000 bushels, valued at $27,652,000; wheat, 11,529,000 bushels, valued at $20,434,000; and rice, 8,468,000 bushels, valued at $13,486,000. For this period the average acre yield of barley was 1,200 pounds, valued at $24.75; of wheat, 880 pounds, valued at $22.66; and of rice, 2,610 pounds, valued at $95.31. The average acre value of rice during this 3-year period has been 3.8 times that of barley, 4.2 times that of wheat, 2.3 times that of corn, 4.4 times that of oats, and 3.2 times that of grain sorghum.

By contrast, rice sown on one-eighth of the average barley acreage has produced nearly half as much agricultural wealth. Sown on less than one-fifth of the average wheat acreage rice has produced nearly two-thirds as much agricultural wealth. Rice is grown chiefly on land which was used for wheat and barley culture prior to the introduction of rice, so under rice culture this land is much more productive than it was when wheat and barley were grown.

RICE-GROWING REGIONS.

There are five main rice-producing regions in the United States:

(1) The coastal plains of the Carolinas and Georgia, where rice has been grown for more than 200 years. Prior to the Civil War rice growing was a profitable industry in this section, but at present the crop is of little agricultural value.

(2) The alluvial bottom lands along the Mississippi River in Louisiana, where rice growing began commercially in 1865. The irrigation water for this section is obtained mostly from the river by means of siphons.

(3) The broad level prairie region of southwestern Louisiana and southeastern Texas, where rice growing began on a commercial scale about 1885. The irrigation water for this section is obtained by powerful pumps from sluggish streams or bayous, which provide drainage for the prairies. Water is also pumped from deep wells. This is the most important rice-producing region in the United States.

(4) The prairie region of eastern Arkansas, where rice growing began commercially in 1905. The irrigation water for this section is pumped from deep wells.

(5) The interior valleys of California, where rice growing began on a commercial scale in 1912. The irrigation water for this section is obtained largely from the Sacramento and Feather Rivers by gravity and by pumps.

REQUIREMENTS OF THE CROP.

Successful rice culture is dependent upon (1) high temperatures during the growing season, (2) a dependable water supply during the period of irrigation, (3) soils that are comparatively flat or level and underlain with an impervious subsoil, and (4) good surface drainage.

In tropical and subtropical countries rice is the standard cereal crop, and it is also grown in the warmer sections of the Temperate Zone. British India, China, Japan, Burma, and the Philippine Islands are the leading rice-producing countries of the world.

In California continuous submergence of the land to a depth of 4 to 6 inches for 90 to 140 days each year is necessary for the production of profitable rice crops. It is also necessary to flood the land after sowing, to germinate the rice seed. A dependable supply of irrigation water, therefore, must be available when needed.

The clay and clay-adobe soils of California, which have an impervious subsoil from 3 to 6 feet below the surface, are best adapted to rice culture. Such soils require less water to produce a crop than do the lighter soils. After draining in the fall, these heavy soils usually dry out and crust at the surface more quickly than lighter soils, thus making possible the use of heavy machinery in harvesting the crop. Level land can be prepared for rice irrigation at a much lower cost per acre than slightly rolling or rough land. The larger checks on level land are also more economical to harvest than the small checks necessary on uneven land.

Good drainage is as essential in rice culture as in wheat culture, for without adequate drainage it is difficult to obtain good stands in the spring and practically impossible to drain the land thoroughly for harvest when the crop is nearing maturity. Poorly drained fields are hard to cultivate and expensive to harvest. It therefore is essential to have good surface drainage if maximum yields are to be produced at a minimum cost.

CLIMATE.

In the Sacramento and San Joaquin Valleys the summers are hot, with low humidity. The hottest months are June, July, and August, with maximum temperatures ranging from 105° to 115° F. A daily range in temperature during these months of 40° is not uncommon. The nights are comparatively cool, even during the hottest months. The winter months are usually mild, though freezing temperatures are not uncommon during December, January, and February. These are also the months of highest precipitation. All precipitation is in the form of rain. The average annual rainfall at the Biggs Rice Field Station for the nine-year period from 1913 to 1921 was 21.7 inches.

The average evaporation from a free water surface from April 1 to October 31 was 42.8 inches. Strong winds seldom occur, though there is often considerable wind during the early spring and late fall months.

SOILS.

The rice crop in California is grown on various soil types. The heavy clays and clay adobes which are underlain with an impervious subsoil at depths ranging from 18 to 36 inches appear to be best adapted to this crop. These heavy soil types are hard to cultivate. If plowed when too wet they bake; if too dry they turn in large clods, which are difficult to reduce. These soils require from 4 to 6 acre-feet of water to mature a rice crop, while lighter soils may require from 7 to 10 acre-feet. Heavy soils when drained in the fall usually dry out and crust at the surface in from 10 to 14 days, so that they will support heavy harvesting machinery, while most light soils dry more slowly and do not crust at the surface as quickly, so that it is often necessary to harvest in the mud. Harvesting under such conditions is very expensive.

ROTATIONS.

The rice industry of California is comparatively young, and no definite system of rotation is yet being followed. The heavy soils on which rice is grown and the high water table during the submergence season make it difficult to find crops that can be grown profitably in a rotation with rice. The nearest approach to a rotation system at present is on land on which two or three rice crops have been grown. These rice crops are followed by spring or summer plowed fallow on which wheat or barley is fall sown, and then rice is again grown for one year. By this method only one rice crop is grown on the same land once in three years after the original crops on new land. A second method is to alternate a rice crop and fallow. The rice stubble is irrigated and pastured or spring-plowed for fallow; then prepared for rice the following spring. Some do not fallow but leave the land uncropped and uncultivated until it is prepared for rice the following spring.

At the Biggs Rice Field Station attempts have been made to grow cultivated crops in rotation with rice, but neither corn, grain sorghums, cotton, nor beans have produced a profitable crop. Until more information is available on other crops it seems advisable to

use the crops that were produced before rice growing began, i. e., wheat and barley. These crops mature before the water table has risen sufficiently to interfere with growth. Some very good yields of wheat and barley have been reported on fallowed rice land, although some growers do not think that these crops are profitable under such conditions. These growers prefer to alternate rice and fallow or to have two rice crops and one fallow. The growing of wheat or barley following rice without fallowing is seldom practiced, for the yields obtained are usually low.

FERTILIZERS.

The three plant-food elements most likely to be deficient in soils are nitrogen, phosphorus, and potash. When deficient, these elements can be added to the soil in the form of manure and commercial fertilizers.

Fertilizers are not now used on the California rice fields. Each year, however, more growers are making inquiry regarding the possibility of maintaining or increasing yields by the use of fertilizers. The water used for irrigation in California is comparatively pure and therefore adds but little, if any, plant-food elements to the soil.

The new rice lands are very productive, but yields are usually materially lower with each successive crop. The reduced yields may be due to a lack of plant-food elements, competition with weeds, poor physical condition of the soil, lack of humus, poor drainage, unfavorable conditions for soil microorganisms, or other causes.

Fertilizer experiments with rice at the Biggs Rice Field Station indicate that the Stockton clay-adobe soil is deficient in nitrogen. It is quite possible that other rice soils of California are also deficient in this element. Nitrogen can be added to the soil as commercial fertilizer or by growing a leguminous crop to be plowed under. The second method should be followed wherever possible, as it adds humus and thus improves the physical condition of the soil as well as supplying nitrogen. Decaying humus also helps to make other plant-food elements more readily available. No legumes are now known to do well on California rice lands, but such crops may be found.

Rice yields at the Biggs Rice Field Station have been materially increased by the application, just before seeding, of manure at the rate of 1 ton per acre, of ammonium sulphate at the rate of 100 pounds per acre, of dried blood at the rate of 160 pounds per acre, and of cottonseed meal at the rate of 280 pounds per acre. The increased yields were sufficient to give a fair profit after deducting the cost of the fertilizer and its application.

Investigations indicate that rice may use nitrogen in the form of ammonia, while most cultivated plants use nitrogen in the form of nitrates. Rice is grown on submerged land which is unfavorable for the formation of nitrates, but some ammonia compounds are formed. The application of nonnitrogenous fertilizers at the Biggs Rice Field Station failed to increase yields materially. The nitrogenous fertilizers if applied in too great quantity are likely to cause lodging; they therefore should be used with care.

The fertilizer experiments at Biggs indicate that, except for manure, ammonium sulphate applied at the rate of 100 pounds per

acre or dried blood applied at the rate of 160 pounds per acre produced the largest and most profitable increases in yield. These fertilizers quite possibly can be used with profit on commercial fields.

WATER SUPPLY.

The Sacramento and Feather Rivers, which are fed by melting snows in the Sierra Nevada Mountains, supply most of the water used for rice irrigation in the Sacramento Valley. Private companies divert the water from these rivers by gravity or by large pumps. The water is distributed to the growers by a system of canals and laterals and sold on an acre-foot basis or at an annual charge per acre. Very little rice is irrigated from deep wells in the Sacramento Valley, but in the San Joaquin Valley deep wells are often the only source of water. Deep wells are expensive to dig, equip, and operate and should not be depended upon for rice irrigation until they have been thoroughly tested. If wells are to be used they should be ready to operate before the rice is sown. In California it is necessary to apply water to germinate the seed, and thereafter irrigations must follow often enough to keep the land moist and in good condition for crop growth or the water must be held continuously.

PREPARATION OF LAND FOR IRRIGATION.

Most of the land on which rice is grown in California is comparatively level, with a gentle slope varying from 2 to 5 feet per mile. Such land can be prepared for rice irrigation with little expense. A competent surveyor should be employed to locate the supply ditches, the drainage ditches, and the field levees. The improper location of these ditches and levees often causes serious losses. The supply ditches should be properly located and large enough to furnish ample water when needed. The drainage system should be adequate to dispose of the water promptly when desired. The usual method of connecting the various points on a contour line is to follow the rodman with a plow, the plowed furrow indicating the base of the levee. A tractor drawing 10 or 12 plows then makes one round, backfurrowing to the furrow made by the team. This provides loose ground for building the levees. Sharp turns in levees should be avoided when possible, for such turns make the levees hard to build and the crop difficult to harvest.

The outside levees should be well constructed and higher than the field levees, to avoid seepage and loss by overflowing. The outside levees often serve as one bank of the supply or drainage ditch and when so used are often built with a Fresno scraper. The interior or field levees are usually made with a checker drawn by one or two tractors, depending upon the size of the checker or of the tractors used. The checkers are usually equipped with some device for raising and lowering the rear end, which enables the operators to lift it when moving from levee to levee and in a measure to control the size of the levee. When the ground is rough or trashy the checkers are often weighted so that they will push enough soil together to form a good levee. On large fields these outfits can build from 10 to 15 miles of levees in a day.

The checkers are usually homemade and are variable in size. The runners for the sides are generally made of 3-inch by 12-inch plank 16 to 24 feet in length and are lined with steel. The front end is from 10 to 18 feet wide on the bottom. and the rear end is 3 to 6 feet wide on the bottom. The sides are made 2 to 3 feet high and are set on a batter, or slant, of $\frac{1}{4}$ to 1, the tops sloping outward. A tractor-drawn checker is shown in Figure 2.

It requires more power to pull a large checker than a small one, but the levees constructed by a large checker are much more serviceable and economical than those poorly built with a small checker. Poorly constructed levees often result in low yields of rice of poor quality. Levees on small fields are often built with a ditcher or V crowder.

The checkers are pulled with the wide end forward, the loose surface soil being drawn through to the small end. This makes a levee from 12 to 24 inches high and from 4 to 6 feet wide at the base.

FIG. 2.—A tractor-drawn checker used in constructing levees in California rice fields.

It is impossible to connect the field levees and outside levees with the tractor and checker, owing to the space needed for turning. Therefore, the ends of the field levees must be built to connect with the outside levees by using the Fresno scraper. This work should be done before the fields are seeded.

At convenient places in the levees irrigation boxes should be installed to facilitate irrigating. The boxes should be placed deep enough so that the bottom boards will not hold the water back when the fields are draining. The depth of water is controlled by shutters which are held in a vertical position across the openings of the irrigation boxes. By taking out or putting in a narrow board shutter the water can be lowered or raised as desired.

Leveling the land within a check is not commonly practiced in California. Where high spots are removed to fill in low places, the crop on the fills grows very rank and does not mature well, while on the scraped places the growth is stunted.

On old rice land an unequal depth of submergence in the check does not materially affect the date of maturity of the rice crop, but on new land unequal depths of submergence may result in the uneven ripening and inferior quality of the grain.

SEED-BED PREPARATION.

In preparing the seed bed the land should be spring-plowed 4 to 6 inches deep as early as it can be worked to advantage. In a week or 10 days after plowing the land may be disked or harrowed. A few days later it is dragged with a heavy drag. If the land is very cloddy, it is often dragged two or three times. Disking and harrowing are often omitted and the clods are crushed with heavy drags. The time that elapses between plowing and the other cultural operations gives the weather an opportunity to reduce the clods; in fact, the action of the weather on clods during these intervals is often more effective than cultivation in preparing a good seed bed. A light rain followed by a few warm days is very effective in reducing clods.

Very little California rice land is fall-plowed. The reason for this is that rice is harvested late in the fall, in October and November, and rains may occur before threshing is completed. By the time harvest is completed the land is usually too wet to plow. Some rice land is fall-plowed in exceptionally dry years. Fall-plowed land, through the action of rain and sun during the winter months, is easily reduced to a good seed bed the following spring. On the other hand, weeds, especially canary grass and wild oats, start growth on fall plowing during the late winter and early spring months and are difficult to kill unless the land is replowed shallow in the spring, which makes the seed-bed preparation expensive. If weed growth is killed on fall-plowed land before sowing, the cost of preparing a seed bed on spring-plowed and on fall-plowed land is about equal. Yields are similar on fall and spring plowing.

A slightly rough seed bed is preferable to a finely pulverized one when rice is sown broadcast and not harrowed. Finely pulverized seed beds have a tendency to run together after irrigation and remain cold and unfavorable for germination and early growth, while one which is slightly rough does not run together so much and is more favorable for germination and early growth. The seed bed should not be too finely pulverized, nor should it be so rough that it is difficult to see the drill marks if a drill is used.

Rice sown on disked stubble does not yield as well as that on plowed land. The disked stubble provides better conditions for the growth of cat-tails, spike rush, umbrella plants, slender aster or ironweed, and other weed pests. It pays to kill all growth before sowing rice.

VARIETIES TO GROW.

There are two main groups of rice, glutinous and nonglutinous. The nonglutinous rices are grown most extensively in all rice-producing countries. Based on method of production there are two general types of rice, lowland and upland. Based on kernel shape and size, rices are classed as long-grain, medium-grain, and short-

grain varieties. The commercial varieties grown in California are nearly all short-grain rices, and all are of the lowland or irrigated nonglutinous type. The short-grain rices are hardy, yield well, and usually mill well, but the best varieties require a comparatively long growing season. Early rices are desirable in California, but in addition to earliness they must have stiff straw and the ability to produce high yields of good milling quality.

Many early rice varieties are known, but earliness, stiff straw, high yield, and good milling quality are seldom combined in one variety. Earliness is easy to secure, but the desirable combination of other characteristics with it is hard to find. Earliness in rice, as in most crops, is often associated with low yields and inferior quality instead of high yields and good quality.

The varietal experiments at the Biggs Rice Field Station show that the short-grain rices are better adapted to California conditions than the medium or long grain varieties. The early and midseason short-grain varieties are grown most extensively in California and produce much better crops than the medium and long grain rices.

A variety of rice known to be adapted to the section in which it is to be grown should be sown in preference to some new and unknown variety. New varieties should not be sown extensively until they have been tested in comparison with the leading local varieties. Frequently the sowing of a new variety before it has been tested results in considerable loss to the growers. The new variety may not be adapted to the section, or may have a weak straw, or may produce low yields of poor quality. Each year some new early-maturing variety appears in California which, according to press statements, will revolutionize the rice industry, but in the past these varieties have had one or more weak points which have prevented them from coming up to the advance notices. It is best to use home-grown seed of an adapted variety which is known to produce good yields of good quality.

The commercial varieties in California are quite badly mixed. The varieties become mixed from volunteer growth when growers change varieties. The varieties are also mixed in threshing when a grower produces more than one variety. These mixtures are undesirable, because the different varieties usually vary in kernel size and mature at different dates, which results in an inferior quality of rice.

It would probably pay growers to maintain seed plats on their farms on which they could rogue out the mixed varieties and inferior plants. If the crop from such plats is carefully threshed and cleaned, growers could produce their own seed of a known variety of good quality and free from mixtures. Growers who do not wish to take the trouble to raise seed rice in a seed plat can usually obtain good seed from someone who specializes in seed production. It is discouraging to see a pure-line variety, the development of which has required the spending of considerable time and money, become badly mixed after being grown commercially for two or three years.

The leading varieties of rice in California are discussed in the paragraphs which follow.

WATARIBUNE.

Wataribune (fig. 3) was the leading rice variety grown in California from 1912 to 1917. This rice was brought to California by the United States Department of Agriculture in 1909. Wataribune (sometimes known as Late Wataribune in California) yields well on new and on old rice land, mills well, and is the hardiest variety grown in that State. It stools well on new and on old land, heads and ripens uniformly, and has a reasonably stiff straw. It does not shatter easily nor is it difficult to thresh. The only objection to this variety is its long growing season, about 168 days from first irrigation to maturity on old land. It is not extremely late on old land, however, as it usually matures from October 15 to 20 if sown reasonably

FIG. 3.—Seed rice of the Wataribune variety. (Natural size.)

early in the spring. If growers are equipped to handle their crop quickly, this variety is usually satisfactory. Like all other varieties it requires a longer growing season on new than on old land.

The grain of Wataribune rice is short and broad. The hull is light yellow and has a light yellowish awn, or beard. The beards may drop before the rice is harvested or at harvest time, so that only a few of them are present in the threshed rice.

EARLY WATARIBUNE.

Early Wataribune is one of the leading varieties in California. This variety was introduced from Japan by W. K. Brown in 1913. Early Wataribune is not a pure variety but is slightly mixed and consequently does not head and mature uniformly. It yields well on new and on old land and matures about a week to 10 days earlier than Wataribune. It mills well and is popular with both growers

and millers. On old land it requires about 158 days from the first irrigation until the crop is mature.

The grain of Early Wataribune is short and broad. The hull is light yellow and has a light yellowish beard. The beards usually drop before the rice is harvested or at harvest time, so that the threshed rice is usually beardless.

CALORO.

Caloro rice was developed at the Biggs Rice Field Station and was first distributed in 1921. It is now the leading variety grown in California. It is a pure-line variety which heads and ripens uniformly and yields well on both new and old land. It matures about 4 days earlier than Early Wataribune. The grains are short

FIG. 4.—Seed rice of the Colusa variety (C. I. No. 1600). (Natural size.)

and broad and, like those of Early Wataribune, have short yellowish beards, which usually drop before the crop is harvested and threshed. Caloro heads quickly, ripens evenly, and usually yields better than Early Wataribune. On old rice land Caloro requires about 155 days from the first irrigation until the crop is mature.

COLUSA.

The Colusa variety (C. I. No. 1600) is an early short-grain rice distributed by the Biggs Rice Field Station. It was developed from a selection originally made at the Crowley Rice Experiment Station, Crowley, La. Colusa is 10 days to two weeks earlier than Early Wataribune, requiring about 145 days from the first irrigation until the crop is mature on old rice land. It yields well on new land but

not on old rice land unless the latter is quite productive. Colusa is especially well adapted for growing on new land, but is inclined to lodge if the land is very rich. The grains are short and broad, light yellow, and beardless.

ONSEN.

The Onsen variety is an early short-grain rice introduced from Japan by a Japanese in 1918. Onsen is about two weeks earlier than Early Wataribune and yields well on new land but has a marked tendency to lodge. On old land Onsen does not, as a rule, yield as well as Early Wataribune or Caloro, but appears to be better adapted in some sections than Colusa. Onsen is not a pure-line variety but is mixed. Most of the crop is very similar to Colusa, though the grains may be slightly larger. They are short and broad, mostly beardless, and the hull is light yellow. On old rice land Onsen requires about 142 days from the first irrigation until the crop is mature.

SEED.

After deciding upon the proper variety to grow, one which is adapted to the locality, has stiff straw, and yields and mills well, it is important to have a supply of good seed of that variety. Good seed rice should be graded and cleaned with a fanning mill. It should be free from red, immature, dehulled or broken rice or the seeds of other rice varieties or weeds. Good seed rice should be well filled and uniform in size. Uniformity in size and ripening is more important in rice than in other cereals, because the value of rough rice is based upon the percentage of head rice obtained in milling. Larger yields of head rice are obtained from well-matured rough rice consisting of grains of uniform size of one variety than from poorly matured rough rice consisting of grains of various sizes and a mixture of varieties.

The use of seed rice containing immature, dehulled, or cracked grains often results in poor stands which ripen unevenly and produce low acre yields of inferior quality. Grasses and weeds increase the cost of production, reduce yields, and lower the market value of the crop produced. Mixed varieties that mature at different times and vary in kernel size are very undesirable in rice.

Poor stands can often be improved by sowing in an early-maturing variety of the same type as that originally sown, but this practice is not to be recommended except in extreme cases, and the crop produced should not be used for seed the following year. Economy in crop production is desirable, but it is false economy to use poor seed rather than to pay a slightly higher price for good seed.

If there is any doubt regarding the germinating power of the seed, it should be tested before it is sown. To make a germination test, count out several lots of 100 seeds from the seed to be sown, place the lots separately between blotting papers, and keep moist at a temperature of 75° F. for about 10 days. Then count the seeds that have strong sprouts and figure the percentage of germination. If seed of low germinating power must be sown, the rate of seeding should be materially increased.

SEEDING.

METHOD OF SEEDING.

Rice is sown with a drill or broadcast with an end-gate seeder. Both methods of seeding are commonly used. On well-prepared seed beds the drill distributes the seed more evenly and at a more uniform depth than is possible with broadcast seeding, and ordinarily less seed is required. Drilled rice usually germinates and grows more uniformly than broadcast rice. On comparatively rough and rough seed beds rice is generally sown broadcast. On such seed beds drilling is too slow and expensive, and the seed is not placed at a uniform depth or covered evenly. Drilling is slow, uniform, and expensive, while broadcasting is rapid, not uniform, and inexpensive. Broadcast rice is not usually harrowed after sowing, for the first irrigation water will slack enough clods to bury the seed.

DATE OF SEEDING.

The best date to sow rice in California varies with the soil and climatic conditions from year to year. Rice may be sown between April 15 and June 1, but for the best results with the usual method of irrigation and when soil conditions and temperature permit, it should be sown as early as possible. There is less danger of losses from fall rains when the crop is sown early and matures early.

A variety of rice has a tendency to mature within a certain period regardless of the date of seeding, but yields are higher from the early dates of seeding. In a date-of-seeding experiment at the Biggs Rice Field Station in which Wataribune rice was sown as early as soil conditions permitted and at 15-day intervals thereafter until June 1 there was a marked decrease in yield with each successive date of seeding.

The earliest date of seeding produced a 9-year average of 400 pounds per acre more than the second date, and 500 pounds per acre more than the third date. The late-sown rice was of poorer quality each year than the early-sown rice.

It has been observed also that early-sown commercial fields as a rule produce higher yields of better quality than late-sown fields.

Light soils are warmer early in the spring than heavy soils and for this reason can be sown earlier. Rice sown in a cold soil and irrigated with cold water during a period of low temperatures usually germinates poorly, and often three weeks elapse before the plants emerge. Under such circumstances seeding should be deferred until conditions are more favorable for germination and growth. Under such variable conditions as exist in California no best date of seeding can be recommended. However, late-maturing varieties should be sown as early as weather and soil conditions permit, from April 10 to 25, midseason varieties may be sown from April 15 to May 15, and early varieties from April 20 to May 20.

RATE OF SEEDING.

The rate of seeding depends upon—

(1) The variety used. Early-maturing varieties stool less than late-maturing ones, and for this reason more seed of them should be sown.

(2) Quality of seed used. Poorly matured seed does not germinate as well as fully matured seed, and for this reason seed of inferior vitality should be sown at a higher rate than well-matured seed.

(3) Fertility of the soil. On rich soils less seed is required than on poor soils, because the crop will stool more on rich soil.

(4) Condition of the seed bed. Less seed is required on a well-prepared seed bed than on a poorly prepared one, because the percentage of germination is higher on a well-prepared than on a poorly prepared seed bed.

(5) Method of irrigation. Good stands are dependent upon proper irrigation when the crop is being irrigated up. Small heads of water during the initial floodings often result in poor stands, owing to the long time required to cover and drain the fields. If the water must stand on the fields for several days, the rate of seeding should be heavier than when it can be irrigated and drained properly.

(6) Date of seeding. Less seed is required to obtain an optimum stand late in the season than earlier, for conditions are then more favorable for prompt germination and growth.

(7) Method of seeding. As a rule, less seed is required on well-prepared seed beds when drilled than when sown broadcast.

(8) Drainage. Good drainage is essential to obtain good stands. If the drainage is poor the rate of seeding should be increased, so that if the seed rots there will be less injury to the stands.

(9) New or old land. Less seed is required to obtain optimum stands on new than on old rice land, because conditions are more favorable for germination and the rice stools better. Thin stands may induce excessive stooling, resulting in nonuniform heading and ripening and often in low yields of poor quality. Good stands prevent excessive stooling and tend to produce uniform heading and ripening and high yields of good quality.

Late-maturing varieties should be sown at the rate of 100 to 110 pounds per acre on new land and 120 to 130 pounds on old land. Midseason varieties should be sown at the rate of 115 to 125 pounds on new land and from 125 to 135 pounds on old land. Early varieties should be sown at the rate of 120 to 130 pounds on new land and from 130 to 145 pounds per acre on old land.

DEPTH OF SEEDING.

The depth at which rice should be sown depends upon—

(1) Character of the soil. Rice can be sown deeper on a light warm soil than on a heavy cold one, because the seed will germinate and emerge more quickly.

(2) Condition of the seed bed. On poorly prepared seed beds the seed should be sown shallower than on well-prepared beds, because if sown 2 inches deep on a poorly prepared seed bed the first irrigation water will slack the clods and cover the seed to a depth of perhaps 3 to 4 inches, which is too deep for best results.

(3) Drainage. On land that can not be well and promptly drained, shallow seeding is preferable to deep seeding, because rice covered with soil and water germinates poorly and much of the seed rots, but it germinates well under water if the seed is not covered with soil and conditions are favorable for germination.

In a depth-of-seeding experiment at the Biggs Rice Field Station in which rice was sown 1, 2, and 3 inches deep, that sown at the 1-inch depth produced an average acre yield of 250 pounds more and that at the 2-inch depth a yield of 370 pounds more than that sown at the 3-inch depth.

On light warm soils rice should be sown 2 to 3 inches deep, and on heavy, cold, but well-drained soils, 1 to 2 inches deep. On poorly drained land and poor seed beds, it is better to have some seed on the surface than to sow too deeply.

IRRIGATION.

On the heavy soils used for rice culture in California it is necessary to apply water to germinate the seed. The usual irrigation season is therefore divided into two periods. The first period consists of frequent irrigations, followed by drainage, to germinate the seed and to keep the crop growing well until about 30 days after emergence, when the second period, or period of submergence, should begin. Good stands are occasionally obtained by early seeding on light soils without irrigation to germinate the seed, but such cases are rare. On heavy soils rice should not be sown until water for irrigation is available.

During the first irrigation period when the water is applied to start germination, the water, soil, and air temperatures are usually much lower than they should be to insure prompt germination. Usually two irrigations are necessary to get the plants up. With the first irrigation it is not so essential that the water be drained from the field quickly, though it should not remain on the land more than 2½ days. After the first irrigation the soil should not be allowed to dry out enough to injure the germinating seeds.

The second irrigation is the critical one, and unless the field is irrigated quickly and drained promptly the stands obtained are very likely to be thin and disappointing. When the crop is up it should receive frequent irrigations to keep the soil in good condition for growth. This will require an irrigation once each week or 10 days, depending upon the soil and climatic conditions, until the rice is submerged. At the last irrigation preceding submergence, the water should be drained off very slowly in order to stretch the plants in the low spots so that they will not be injured by deep water when submergence begins.

Irrigation experiments at the Biggs Rice Field Station show that the rice land should be submerged to a depth of 6 inches 30 days after the plants have emerged. During the submergence period enough water should be entering the checks at all times to replace the losses by seepage, evaporation, and transpiration, and to maintain the desired depth of submergence.

When the rice is submerged, water flows from check to check, and normally there is little danger of any part of the field becoming stagnant if the water is maintained at a constant depth. Therefore it is not necessary, on lands that are free from alkali, to have water overflowing the last check into a drainage ditch. Water is valuable and should not be wasted in this way.

Profitable rice crops can not be grown in California without submerging the land continuously for 90 to 140 days. Rice grown on land kept moist but not submerged is dwarfed and produces small heads and low yields of poor quality.

The quantity of water required to produce a crop of rice depends on—

(1) The topography of the land. Land with natural sloughs or drainage courses passing through it requires more water than land with no natural drainage, because some water will pass through the levees into these sloughs and be lost.

(2) The character of the land. Light open soils require more water to produce a rice crop than heavy soils underlain with an impervious subsoil.

(3) The levee construction. Fields with poorly constructed outside levees lose more water by seepage than fields inclosed by well-constructed levees.

(4) The irrigator. Good irrigators appreciate the value of water and do not waste it; others apparently do not appreciate its value and often waste it. Basing water charges on the volume delivered rather than fixing them at a flat rate per acre would tend to conserve the water and to confine rice growing to the heavy soil types, on which about 5 acre-feet of water are required to produce a rice crop.

Other methods of irrigation are discussed under the heading of water-grass control.

DRAINAGE.

The importance of good drainage should not be underestimated in rice production. Poorly drained land is usually expensive to cultivate, difficult to obtain good stands on, and seldom produces maximum yields. Weeds, such as cat-tails, umbrella plants, spike rush, and grasses, are more difficult to control on poorly drained than on well-drained land. Harvesting is usually more expensive on poorly drained than on well-drained land, and there is often a loss due to overripeness which results in shattering. Before the rice is sown or irrigated it is advisable to provide drainage for the low places in the field, so that it can be well drained during the flooding season and before harvest.

Good judgment must be used in deciding when the rice crop is ready to drain for harvest. No set rule can be given as to the proper time to drain, because so many factors must be considered. Some soils dry quickly after draining, others very slowly. It is evident, therefore, that the water should be held longer on soils that dry quickly than on those that dry slowly. As a rule, heavy soils dry slowly, but they crust or bake at the surface much more quickly than light soils. For this reason, some light soils should be drained earlier than heavy soils, because more time is required to form a crust at the surface which will support harvesting machinery. The weather has a marked influence upon the date of draining. Naturally, it takes longer for the soil to dry with poor drying weather than with good drying weather. It usually takes from 10 to 18 days after draining until the land is dry enough to support harvesting machinery. The levees should be cut in many places so that all water can be drained from the low spots in the field.

Prior to draining the land for harvest, no water should be allowed to enter the fields for about a week. This gradual lowering of the water is desirable because rapid draining has a tendency to weaken the rice straw and cause lodging. Large quantities of drainage water also may damage crops located on lower lands.

Rice should be drained early enough to permit the ground to become dry, so that it will support harvesting machinery by the time that the crop is practically mature. It is usually ready to drain when the heads are well turned down and the lower kernels on the heads are in the soft-dough stage. At this time the upper two-thirds of the kernels on the heads are usually turning yellowish in color.

The rice varieties grown in California require about 42 days from first heading until they are mature. About 10 days elapse from the time the first heads appear till the crop is fully headed. The first heads are ripe about 10 days after full heading, and the crop is fully mature about 22 days after the first heads ripen.

After the rice heads are well turned down, they appear to mature as well in shallow as in deep water. When rice is drained too early the yield is reduced and some kernels are immature, resulting in inferior quality. When drained too late there is often a loss due to overripeness, with resulting shattering during harvest and possible lowering of quality due to sun cracking.

More rice is probably damaged in California as a result of draining too early than from draining too late. Rice drained at the right time is ready to harvest before it is overripe and yet not immature. At this stage it yields best and mills well.

Drainage ditches should be cleaned during the slack season prior to draining for harvest, so that the fields can be drained promptly if necessary.

Harvesting in the mud will soon take the optimism out of an optimist and materially reduce the profits of an otherwise profitable crop.

For many years little attention was given to the drainage problem, but now several drainage districts have been organized. Considerable draining has been done and more will be done from year to year. With better drainage the duty of water will probably be reduced.

Drains should be kept open during the winter months. This will prevent water-logging and the accumulation of alkali salts in the surface soil. Good drainage also aids in the aeration of the soil, which is distinctly beneficial to rice lands.

HARVESTING THE CROP.

Rice is ready to harvest usually in from 10 to 18 days after draining. At this time the heads should be well turned down, yellowish in color, and the lower kernels on the heads in the hard-dough stage. If harvested before this stage of development, the quality may be lowered and the yields reduced by the presence of immature kernels. If harvested after this stage there may be a loss from shattering and sometimes from inferior quality due to sun cracking.

Binders are used in harvesting the rice crop. Most of the binders are equipped with small auxiliary engines, so that they will continue to cut even though the bull wheel slides in the wet or muddy ground. Binders without the auxiliary engines are often used on the drier ground. Three or four horses or mules pull the binders. Small tractors are often used on 8-foot binders when cutting conditions are favorable. The best stock and binders should be used in opening the checks, i. e., making the first round.

Binders and engines should be repaired before harvesting starts, so that costly delays will not be experienced after the harvesting begins. Usually one binder should be available for each 50 to 60 acres of rice.

SHOCKING.

The short-grain rices are the principal varieties grown in California. When the kernel of short-grain rice is ripe, the straw and leaves are still partially green. The harvested rice should, therefore, be put in small shocks to facilitate prompt and proper curing. About one day after rice is cut the bundles should be put in small shocks of six to eight bundles each (fig. 5). The bundles should be set firmly on the butts and the shocks well built, to avoid falling or blowing over. Slow curing and protection from the sun improve the milling quality of rice. Rice shocks usually dry slowly in California and for this reason are seldom capped, for the caps delay curing too long. Capped shocks hold the moisture from dews and light showers and thus delay threshing in the morning. Capping shocks is expensive, and since the caps interfere with morning threshing and prevent the shocks from curing well in a reasonable length of time, it is best not to use them except in extremely wet weather.

FIG. 5.—A field of shocked rice in the Sacramento Valley.

It is poor practice to stand one bundle up by itself, for most of the grain is thus directly exposed to the sun, dews, light showers, and rapid drying, which may result in sun cracking and inferior milling quality.

THRESHING.

In threshing rice the quantity rather than the quality of the work done in a day is too often the standard of a job. Much rice is often wasted because a suitable platform or canvas is not provided to catch the shattered grain. Separators are not well cleaned before changing from one variety to another or from farm to farm, and, as a result, varieties become badly mixed and weed seeds are scattered. Many grains are cracked and the hulls removed by the high speed of the cylinders and by improper adjustment of the cylinders and concave teeth. The cylinder teeth should center between the concave teeth. If the cylinder teeth are to one side or the other, or if the cylinder has side play, the grains of rice will be cracked. Separators and tractors should be overhauled before threshing time in order to avoid costly delays.

Rice should be threshed when the grain is hard and the straw reasonably dry. This will require from 7 to 14 days in the shock, the length of time depending upon weather conditions. Threshing early in the morning, when the grain and straw are damp, often results in poor separation and the loss of grain. Damp rice when stored in sacks may heat and serious losses may result. Careful threshing insures a better grade of rice and larger profits.

Threshing sets should be located on high ground and the sacks of rice put on a bed of straw. (Fig. 6.) The high ground and straw beneath the sacks help to protect the rice in case heavy rains occur before the rice is banked out of the field. Rice should be banked out as fast as threshed; i. e., if 1,000 sacks are threshed per day the same number should be banked out, because there is little chance to get rice out of the field at a reasonable cost after heavy rains. It can, however, be gotten to the warehouse if it is on or near a public road.

DRAYING.

As stated, all rice should be banked out of the field the same day that it is threshed. It should not then be allowed to accumulate

FIG. 6.—Threshing rice in the Sacramento Valley.

along the roadsides. but should be hauled immediately to the warehouse. The cost per sack is much less for banking out of the field and trucking to a warehouse when conditions are favorable than after a heavy rain, when the fields and roads may be practically or totally impassable.

The rice crop is not saved until it is in the warehouse. In the past, during wet autumns considerable rice has been damaged in piles along the roadsides or in the fields. This loss could have been avoided by moving the rice promptly until it was warehoused.

WEEDS.

Weeds are a serious menace to the rice industry of California. Most of the land in rice is badly infested with these pests, which materially decrease yields. Plants that inhabit wet places find conditions in the rice fields ideal for their development. Most of these plants have the characteristic weed habits, which include hardiness, abundant seed production, and shattering, which make them difficult to control or eradicate.

Weeds increase the cost of production, reduce yields, and if the seeds are mixed with the threshed grain lower its price.

Weeds are introduced into the rice fields in five ways: (1) By sowing their seeds with the seed rice, (2) by floods and irrigation water, (3) by birds and other animals, (4) by the wind, and (5) by threshing outfits. Introduction by some of these methods can be avoided. Seed rice containing weed seeds should not be sown. Troublesome weeds should not be allowed to grow along canal banks or in waste places. Animals pastured on foul land should not be transferred to clean land. Threshing outfits should be well cleaned before moving from a weedy to a weed-free farm or field. When only a few weeds appear on the roads, levees, ditch banks, and in the field, they should be pulled by hand or mowed before they mature seed. Weeds are well established throughout the California rice-producing area, so the problem is not, except on new or second-year land, how to prevent their introduction, but how to control or eradicate them.

The worst weeds in the California rice fields are barnyard grasses (*Echinochloa crusgalli* and varieties), cat-tails (*Typha latifolia*), spike rush (*Eleocharis palustris*), sprangle-top (*Leptochloa fascicularis*), umbrella plants (Cyperus), red-stem (*Ammannia coccinea*), red rice (*Oryza rufipogon*), canary grasses (*Phalaris paradoxa* and *P. brachystachys*), crabgrass (*Digitaria sanguinalis*), slender aster (*Aster exilis*), and cheat (*Bromus secalinus*).

BARNYARD OR WATER GRASSES.

Barnyard grasses (*Echinochloa crusgalli* and varieties), which are locally known as water grasses, are the most troublesome weeds in the California rice fields. There are several varieties of water grass, some bearded and others beardless. These varieties differ considerably in date of maturity, height, and size of stems, heads, and seeds. For convenience in discussion of the varieties in this bulletin, they have been placed in four groups:

(1) The early red varieties which grow from 1½ to 2½ feet high, stool heavily and have small stems with rather short, compact heads and small seeds. These varieties have purplish green stems, leaves, and heads and mature and drop most of their seed before the rice is headed.

(2) The midseason varieties, which grow from 3 to 6 feet high, stool quite heavily and have rather coarse stems with comparatively long, loose heads and midsized seed. These varieties usually have purplish green stems, leaves, and heads, the purple color being less pronounced than in the early varieties. They mature and drop most of their seed before the rice crop is fully headed.

(3) The late white varieties, which grow from 2 to 5 feet high, stool heavily and have rather coarse stems with comparatively long, compact heads. One variety has very large seeds, while another has much smaller seeds. The late white varieties do not shatter as readily as the two groups just mentioned, and much seed is present in the threshed rice. The heads of the late white varieties are yellowish green and usually mature before but often with the rice crop.

(4) Other late varieties, which grow from 2½ to 4 feet tall and stool heavily, have midsized stems with comparatively compact heads and midsized to large seeds. One of these varieties has short, stiff red beards, and another is beardless. The plants and heads are about the same color as the rice. They usually mature at the same time as the rice crop.

The barnyard grasses are annuals which usually stool abundantly and produce a large number of viable seeds. These grasses are

quite widely distributed in the United States and are usually found growing along sloughs, irrigation ditches, drainage ditches, on low land, and in marshy irrigated fields. They grow exceptionally well in the California rice fields.

Water-grass seed germinates with the rice, and for about 10 days after emergence the rice grows faster than the grasses. In about two weeks, however, the grasses are taller than the rice, and most of them can be distinguished from it by their purplish green color. The late white varieties are yellowish green and until they begin to head are not easily distinguished from rice by one who is unfamiliar with water grasses.

CONTROL OF WATER GRASSES.

The many varieties of barnyard grass present in the rice fields, ranging in maturity from June 15 to October 20, combined with the long growing season of rice, rather poor drainage, and the apparent ability of the grass seeds to remain in the soil from year to year until conditions are favorable for germination, make their control or eradication a very difficult problem. The problem is further complicated by the fact that much of the rice is grown by tenant farmers, who often have slight interest in preventing the spread of weeds. Several methods for the control of water grasses are suggested in the paragraphs which follow.

Hand pulling.—Water grasses can be destroyed by hand pulling if cut below the crown of the plant, removed from the field, and placed on dry land. Hand weeding is practicable and profitable on new land or on land where the grass plants are few, but this method is too expensive when the grasses are thick. The grasses should be pulled at least once every three weeks from June 15 to September 15 if they are to be kept under control. When the water-grass plants are not numerous hand weeding is effective and pays. It should be rigidly practiced on new land.

Rotation.—Cultivated crops grown in rotation with rice, if kept free from weeds, are helpful in reducing water grasses, but usually such crops on rice lands are unprofitable.

Fallowing.—Spring, summer, or early-fall irrigation germinates water-grass seeds, and the young plants can then be killed by shallow plowing before seed is matured. To insure germination the land should be irrigated and plowed shallow two or three times during the summer. This method is naturally quite expensive. Deep plowing buries the water-grass seeds so deep that they do not germinate but appear to lie dormant in the soil until they are again brought to the surface by later plowing. Water-grass seeds apparently do not rot readily until after germination, and they germinate only when weather and moisture conditions are favorable.

Fall flooding.—Flooding in the fall will germinate some water-grass seed, and the plants may then be killed by frost before seed is matured. This method, however, is not of much practical value.

Submergence.—Control of water grass by early submergence is comparatively new in California, and there are at least three methods which are used quite extensively. In method No. 1 the rice is sown broadcast and submerged immediately to a depth of 5 to 7 inches.

The water is then held continuously at this depth until the crop is ready to drain for harvest. In method No. 2 the rice either is sown broadcast or drilled; then flooded and drained two or three times until the rice emerges. It is then submerged 5 to 7 inches deep and the water held continuously at this depth until the crop is ready to drain for harvest. In method No. 3 the land is submerged 5 to 7 inches deep and the rice sown broadcast in the water, the water then being held continuously at this depth until the crop is ready to drain for harvest.

Each of these methods of irrigation is quite satisfactory in controlling the growth of the early and midseason varieties of water grass, but these irrigation methods apparently do not check materially the growth of the late white varieties. When these irrigation methods are used and the white grasses are not too thick it seems advisable to pull them by hand, to prevent them from increasing and making control by irrigation ineffective.

Methods Nos. 1 and 3 appear to be more effective in the control of grasses than method No. 2.

Five problems in connection with these methods of rice irrigation are now being studied by the United States Department of Agriculture on the rice field station at Biggs and by the California Agricultural Experiment Station at Cortena, Colusa County. These are (1) the best date of seeding and submerging, (2) the most effective depth of water to hold, (3) the best rate of seeding to use, (4) the best seed-bed preparation, and (5) a comparison of the effectiveness of the three methods of irrigation. The recommendations which follow are based on four years' observations on commercial fields and two years' experimental results at the Biggs Rice Field Station.

In method No. 1 the rice should be sown broadcast from May 1 to 10 at the rate of 150 pounds per acre. It should be sown on a smooth seed bed, so that little seed will be covered by slacked clods when the land is submerged. The depth of submergence should be kept constant, at from 5 to 7 inches, as fluctuations in depth may let the grass emerge. Some grass usually is present on high spots which are covered with shallow water, and the levees are usually covered with a dense growth of water grasses and other weed pests.

In method No. 2 the land should be reasonably well prepared, though it need not be as smooth as for method No. 1. The rice can be sown either broadcast or drilled as early as conditions permit at the rate of 150 pounds per acre and irrigated up. When the rice plants appear the field should be submerged to a depth of 5 to 7 inches and the water held continuously until the crop is ready to drain. Fluctuations in the depth of water should be avoided if the grass is to be controlled. Rice will germinate under water, but it does not germinate well if covered with soil and water.

In method No. 3 the land should be reasonably well prepared and submerged to the desired depth of 5 to 7 inches. The water slacks the clods and levels the surface. The rice should then be broadcast in the water from May 1 to 10 at the rate of 140 pounds per acre and the water held at this depth until the crop is ready to drain for harvest.

Method No. 1 is just as effective as method No. 3 in checking the grasses, but more seed is required to obtain a good stand. Method No. 2 is not as effective in controlling the grasses as the other methods, but in this method the stand is determined before the crop is submerged. There is some satisfaction in knowing early in the season whether or not a good stand has been obtained.

The water-grass varieties, with the possible exception of the late white ones, apparently are not water plants and are suffocated when young if water is held on them from 5 to 7 inches deep, while the rice and some white water grasses germinate, stretch to the surface of the water, and make a normal growth. The slender, elongated, rice leaf when it reaches the water surface lies prostrate on it for many days before it becomes erect. At this time strong winds may form waves, and often many plants are pulled up and washed to corners of the checks along the levees. If scum forms on the water surface and bakes on top before the rice has emerged, it often prevents many plants from emerging, with resulting thin stands. Notwithstanding these difficulties the methods of irrigation described are quite effective in the control of water grasses and make it possible to grow profitable rice crops on land which is too foul for rice growing by the usual or old irrigation method. On clean land it is best to follow the old system of irrigation, as unfavorable temperatures and deep water may cause poor stands. On the other hand, continuous submergence of clean land may prevent it from becoming foul.

CAT-TAILS.

Cat-tails (*Typha latifolia*), locally known as tules, grow in sloughs and drainage ditches, on poorly drained land, and in rice fields. The cat-tail is a perennial which spreads by seeds and creeping rootstocks. The cylindrical head of the cat-tail, which ranges in length from 6 to 12 inches, is borne at the end of a round stalk. Each head contains thousands of seeds which are readily spread by wind and water. Deep moldboard plowing followed by thorough drying of the soil is very helpful in the control of cat-tails. Good stands of rice have a tendency to prevent cat-tails from entering a field. They usually appear first in the rice fields in low spots or along the levees where the soil has not been well cultivated and stands of rice are poor. Disking rice stubble instead of plowing it in preparing the seed bed for rice provides favorable conditions for the growth of cat-tails and other weeds. Good seed-bed preparation pays, if for no other reason than that it helps to control cat-tails.

SPIKE RUSH.

The spike rush (*Eleocharis palustris*), locally known as wire-grass, grows on poorly drained land, in shallow ditches, and on field levees and establishes itself in rice fields in the corners of checks and elsewhere where cultivation and drainage are usually poor. The spike rush is a leafless perennial plant which produces seeds at the tapering end of a single round stem. The stems vary in diameter from one-sixteenth to one-eighth of an inch. The spike rush spreads by means of underground rootstocks. It will completely crowd out a good stand of rice, and the crop can not grow where the spike rush is well

established. Good plowing, deep enough to get under the roots and turn them over, followed by thorough drying, is very effective in the control of this weed. The spike rush is not troublesome on land which is reasonably well drained and properly cultivated. Its presence in rice fields often indicates poor seed-bed preparation, poor cultural methods, or poor drainage.

SPRANGLE-TOP.

Sprangle-top (*Leptochloa fascicularis*), locally known as ray-grass, grows well on low land. It has entered the rice fields and is spreading quite rapidly. This grass grows about 2 or 3 feet high, stools heavily, and the fine stems terminate in a panicle. Sprangle-top matures seed from June 20 to October 1. The seeds are very small and are seldom, if ever, found in threshed rice.

Sprangle-top after it emerges will stretch through water more quickly than rice, but it apparently does not germinate readily under water. The seeds germinate as soon as mature, while water-grass seeds do not. The ripe seeds of sprangle-top fall to the water, germinate, and the plants die before they mature seed. Cultivation after germination will aid in controlling sprangle-top, and there is good evidence that under early continuous submergence it may disappear.

UMBRELLA PLANTS.

Three species of umbrella plants (Cyperus), commonly known as sedges, grow in the rice fields. The perennial forms grow on the levees and ditch banks and on poorly drained abandoned land. These forms are not troublesome on well-drained land properly cultivated. On poorly prepared seed beds the perennial forms enter the checks, but improved drainage and good cultivation will rid the fields of them.

The annual form is found most abundantly in the rick checks. It does not make its appearance until after the rice has been submerged. Where stands are thin, and sometimes in good stands, it then appears in abundance. The plants grow from 6 to 18 inches high, and a thick stand of them checks the growth of rice. No method of control is known for this form, for it appears on good and on poorly drained land, on good and poor seed beds, and in thick and thin stands, but it is usually thickest where the stands of rice are thin.

RED-STEM.

Red-stem (*Ammannia coccinea*) is found in shallow drainage ditches, along sloughs, and in rice fields. This plant is increasing in the rice fields, especially where stands are thin. The plant consists of a single stalk, with the flowers borne at the axils of the leaves. When mature the entire plant above ground is red in color; hence the name. The seeds are produced in a round capsule about the size of a small pea. These capsules are often present in the threshed rice and, if green, may interfere with curing in the sack. The base of the stem is covered with a spongelike structure. Good cultivation will no doubt control red-stem.

RED RICE.

Red rice (*Oryza rufipogon*) is usually present in all rice-producing countries of the world. It is the worst weed in the rice fields of the Southern States and has been introduced into California with seed rice. It is not yet common, however, in that State. The infestations should be located and the plants hand-pulled and destroyed. Red rice can be detected in seed rice by hulling a sample of the grain. Red rice has a red seed coat when the hull is removed, while the common rice has a brownish or white seed coat. Seed containing red rice should not be sown. The presence of a few red grains in milled rice reduces its value.

Red rice has a spreading habit of growth, while our commercial rices grow more erect. The heads of red rice are loose, open, and slightly drooping. The grain shatters readily when ripe, and in this way it spreads very rapidly. The rice growers of California should guard against the spread of this troublesome weed pest. Seed rice bought outside the State should be examined carefully for red rice before it is sown.

A red rice, locally known as Italian, which is quite different in growth habit and size of kernel from the red rice just described, is now found in California rice fields. It matures earlier and has a longer grain than the ordinary red rice. Its growth resembles that of the commercial varieties of rice, but the seed shatters more readily. This red rice, like the other, lowers the commercial value of the crop, and seed rice containing it should not be sown.

CANARY GRASS.

Canary grass (*Phalaris paradoxa* and *P. brachystachys*), commonly known as California timothy, germinates during the late-winter and early-spring months and by the time the land is dry enough to cultivate has often made a luxuriant growth. Unless this growth is destroyed in preparing the seed bed it often checks the growth of the rice crop. Soon after the land is submerged canary grass dies, for it is not a water plant. This grass is readily controlled by good seed-bed preparation.

CRABGRASS.

Crabgrass (*Digitaria sanguinalis*) is often present on the field levees, but it seldom enters the rice checks. This grass has a spreading habit of growth and roots from the joints, or nodes, of the stem. It is practically impossible to pull this grass, owing to its method of rooting, but good cultivation tends to destroy it.

SLENDER ASTER.

Slender aster (*Aster exilis*), locally known as ironweed, grows quite thickly on rice-stubble land during the summer months when it is uncropped and not cultivated. When rice is sown on disked rice stubble, there is usually considerable slender aster in the rice crop, but this weed is easily controlled by good cultivation. Its

presence in a rice field usually indicates that the crop was sown on a poorly prepared seed bed.

CHEAT.

Cheat (*Bromus secalinus*) is not a troublesome weed in the rice fields, but often is present in rice grown on poorly prepared seed beds on which the vegetation has not been killed. Because of the difficulty of removing cheat from rough or milled rice, the value of the crop is reduced. Wheat and barley are also objectionable in rough rice. Such growth therefore should be killed before the rice is sown, to avoid a reduction in the price received for the crop.

DISEASES, INSECTS, AND OTHER PESTS.

The California rice-growing sections have not been seriously troubled with either rice diseases or insect pests. Leaf-miners (*Hydrellia scapularis* Loew) damaged some rice at the Biggs Rice Field Station in the spring of 1922 while the leaves were lying prostrate on the surface of the water. The injury occurred on plats submerged continuously from seeding time in an effort to control water grass. The miners shredded the leaves of plants which had not yet assumed an erect position and in conjunction with the deep water killed the plants. Plants which were erect were not damaged.

Blackbirds are troublesome in rice fields in the spring and fall. In the spring large flocks of blackbirds pick up the rice, after broadcasting and before it is irrigated. The writer shot a number of blackbirds in the spring of 1922 and found that their crops contained from 4 to 48 kernels of rice. They no doubt consume considerable rice and may help to cause thin stands. They also damage the rice after heading, when it is in the milk stage. Keeping the blackbirds away by shooting early in the morning and in the evening when they usually feed will be found helpful.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

November 27, 1923.

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